

**RED PLAGUE CONTROL PLAN (RPCP)**

The Control of Cuprous / Cupric Oxide Corrosion (Red Plague) in  
Silver-Coated Copper Wire, Cable, and Harness Assemblies

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## What Is “Red Plague” / (Cu<sub>2</sub>O)?

The sacrificial corrosion of copper in a galvanic cell of silver (cathode) and copper (anode), resulting in the formation of red cuprous oxide (Cu<sub>2</sub>O) and black cupric oxide (CuO).

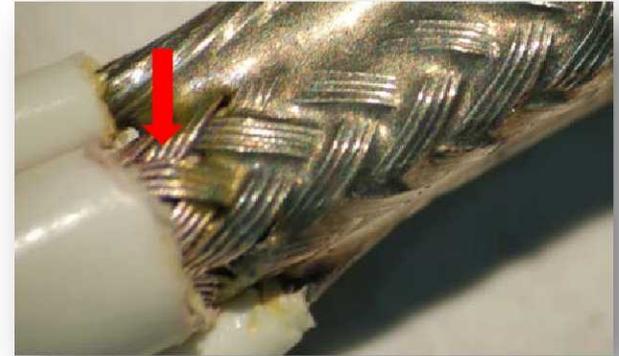
- Promoted by the presence of moisture (H<sub>2</sub>O) and oxygen (O<sub>2</sub>) at an exposed copper-silver interface.
  - Exposed conductor end (**crimp terminations**)
  - Poor plating quality control (**pin-hole, porosity, thin coating**)
  - Mechanical damage during stranding or handling (**scratches, nicks, abrasion**)
  - Corrosion (**chemical, atomic oxygen, silver migration**)
  - Wicking of moisture, oxygen, flux residue, solvents under the Teflon jacket
- Color may vary depending on the amount of oxygen available, commonly noted as a red / reddish-brown surface discoloration – hence the term “Red Plague”.
- Once initiated, the sacrificial corrosion of the copper base conductor can continue indefinitely in the presence of oxygen (O<sub>2</sub>).
- Severity
  - Minor: Some loss of cross-sectional area
    - Most commonly found in shield braiding, but can develop in main conductors
  - Major: Consumption of cross-section, “Silver Straw”

# WHAT MECHANISMS ARE REQUIRED TO INITIATE RED PLAGUE?

## – MECHANICAL DAMAGE

Mechanical damage resulting in exposure of the copper-silver interface.

- Wire manufacturing (i.e.: drawing, stranding, application of insulation jackets, etc.)
- Improper assembly and installation practices (i.e.: tool damage, excessive flexing, improper bend radius, etc.)
- Abrasion by packaging materials (cardboard).



## – ENVIRONMENTAL CONDITIONS

A galvanic cell must form between the copper base metal and the silver coating in the presence of water (H<sub>2</sub>O) and oxygen (O<sub>2</sub>).

- Protection from high humidity and oxygen is considered the greatest significant mitigation against Red Plague.
- Water quench, wet dielectric testing, and aqueous cleaning processes must not be used.

## – INADEQUATE COATING THICKNESS

Porous, discontinuous, and thin silver coatings are more likely to develop Red Plague since a greater number of sites for galvanic cells to form are possible.

- 0.5 micron (~20 micro-inches): Easily damaged during manufacturing and handling
- 1 micron (~ 40 micro-inches): Good flight history, provided procurement and environmental controls used.
- 2 micron (~ 80 micro-inches): Improved resistance to handling / environmental damage and corrosion.

# WHAT MECHANISMS ARE REQUIRED TO INITIATE RED PLAGUE? (cont.)

## – HIGH TEMPERATURE

Migration of the copper base metal through the silver coating

Though the upper continuous operating temperature rating of most silver-coated wiring is +200 C (+392 F), exposure to temperatures approaching +200 C (+392 F) or higher, induces migration of the copper base metal through the silver coating.

- This may reduce the silver coating thickness and create porosity sites for cuprous/cupric oxide corrosion to occur.
- Typically experienced only in long duration operation at temperatures beyond the wire's continuous rating, or where the wiring is exposed to excessive heat during test or highly accelerated burn-in.

## – CHEMICAL ATTACK

Attack and degradation of the mechanical integrity of the silver coating.

Exposure to chemicals present in the environment (oxygen, sulfur compounds, salt, etc.) may result in corrosion and corrosion by-products that attack and compromise the mechanical integrity of the silver coating.

- Common “green” packaging materials often contain and outgas small amounts of sulfur
  - » paper wrapping materials
  - » rubber bands
  - » cardboard boxes
- Exposure to contaminants during transport (diesel fumes)
- Exposure to condensing and corrosive atmosphere (coastal launch facilities)
- Exposure to atomic oxygen (AO) in spaceflight applications has been shown to tarnish and pit silver coatings.

# Why Is Silver-Coated Copper Wire Used?

## Advantages

- Good electrical conductivity
- Excellent:
  - Solderability. Silver improves wettability of SnPb solder
  - Crimpability
    - » Negligible difference in tensile test values for 20, 40, and 80 micro-inch
    - » Isn't hard and slippery like nickel-coated copper
  - Flexibility
- Non-magnetic
  - No signature (useful if you don't want to be seen / detected)
- Low skin effect losses in high speed data and RF transmission applications
- No tin whiskers!!
- Extensive flight experience in US and Europe

# Why Is Silver-Coated Copper Wire Used?

## Disadvantages

- Galvanic Couple: Silver (cathode), Copper (anode) = - 0.46 volt potential
- Environmentally Sensitive
  - Shipping, Storage, Assembly Restrictions
    - » Moisture
    - » Oxygen
    - » Organic compounds (Background gasses – biologic activity; sulfur-bearing materials – cardboard)
  - Application Restrictions
    - » Temperature Limits (+200 C (+392 F) )
      - Inter-strand bonding, silver migration, and oxidation of the copper strands if operated at upper limits for extended periods of time.
    - » Atomic Oxygen
  - Limited Life Article
    - » 10 years from date of manufacture
- Cost
  - Silver tied to commodities market
    - » 40 micro-inch silver is commonly used in spaceflight applications, AS22759
    - » 80 micro-inch is presently considered “special” , MIL-DTL-29606A (Proposed)

# Red Plague Isn't A New / Previously Unknown Concern

Concerns about galvanic corrosion of silver-coated copper wire are in many documents used by NASA, ESA, military, and aerospace.

- **ASTM B 961 – 08** Standard Specification for Silver Coated Copper and Copper Alloy Stranded Conductors for Electronic Space Application
- **ECSS-Q-ST-70-20C** Determination of the Susceptibility of Silver-Plated Copper Wire and Cable to "Red-Plague" Corrosion
- **JPR 8080.5A** JSC Design and Procedural Standards, E-24
- **JSC-49879** JSC Wire & Cable Integrity Compliance Program
- **JSC-49894** Electronic Part Selection and Design Guidelines for Low Criticality Space Flight Payloads
- **MIL-HDBK-338B** Electronic Reliability Design Handbook
- **MIL-HDBK-978B (NASA)** NASA Parts Application Handbook, Vol. 5
- **MIL-STD-1547B (USAF)** Electronic Parts, Materials, and Processes for Space and Launch Vehicles
- **MSFC-STD-3012** EEE Parts Management And Control For MSFC Space Flight Hardware
- **NASA TM X-53522** Evaluation of High Temperature Stranded Hook-up Wire (1966)
- **NASA/TP-2003-212242** EEE-INST-002: Instructions for EEE Parts Selection, Screening, Qualification, and Derating
- **SAE AIR4487** Investigation of Silver Plated Conductor Corrosion (Red Plague)
- **SAE AS50881C** Wiring Aerospace Vehicle
- **TOR-2006(8583)-5236** Technical Requirements for Electronic Parts, Materials, and Processes Used in Space and Launch Vehicles

# WHY DID JSC DEVELOP A RED PLAGUE CONTROL DOCUMENT?

Push-back from the projects and programs, with the view:

- **VAGUE TECHNICAL GUIDANCE**

- “All the documents say is that there is a concern. So What?”
- “No formal requirements / procedures document. No QA criteria. How do I implement?”
- “No failures attributed to Red Plague reported in PRACA or NASA Lessons Learned database.”
- “We have extensive flight experience with silver-coated copper wire. No failures attributed to Red Plague .”
- “All problems were in the past and caused by poor wire manufacturing process controls. Processes are better and we’re smarter!”

**Conclusion:** → **Red Plague is an Urban Myth!**

- **LATENT FAILURE MECHANISM**

- “Red Plague takes +10 years to develop.”
- “My project will ONLY fly for 1 flight, and it’s located in the habitable section of the vehicle.”
- “My project is CRIT 3, and it doesn’t matter if it works or not!”

**Conclusion:** → **Risk of failure is low!**

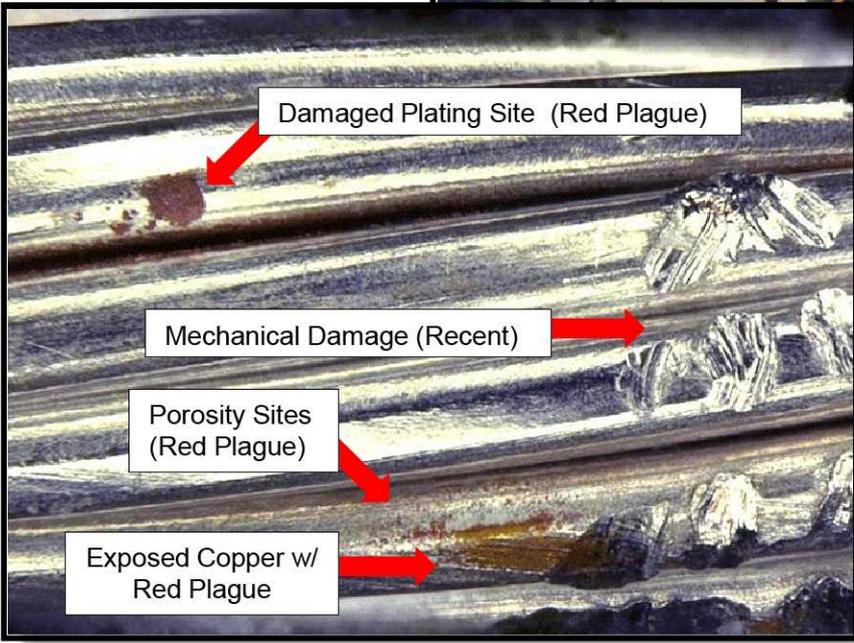
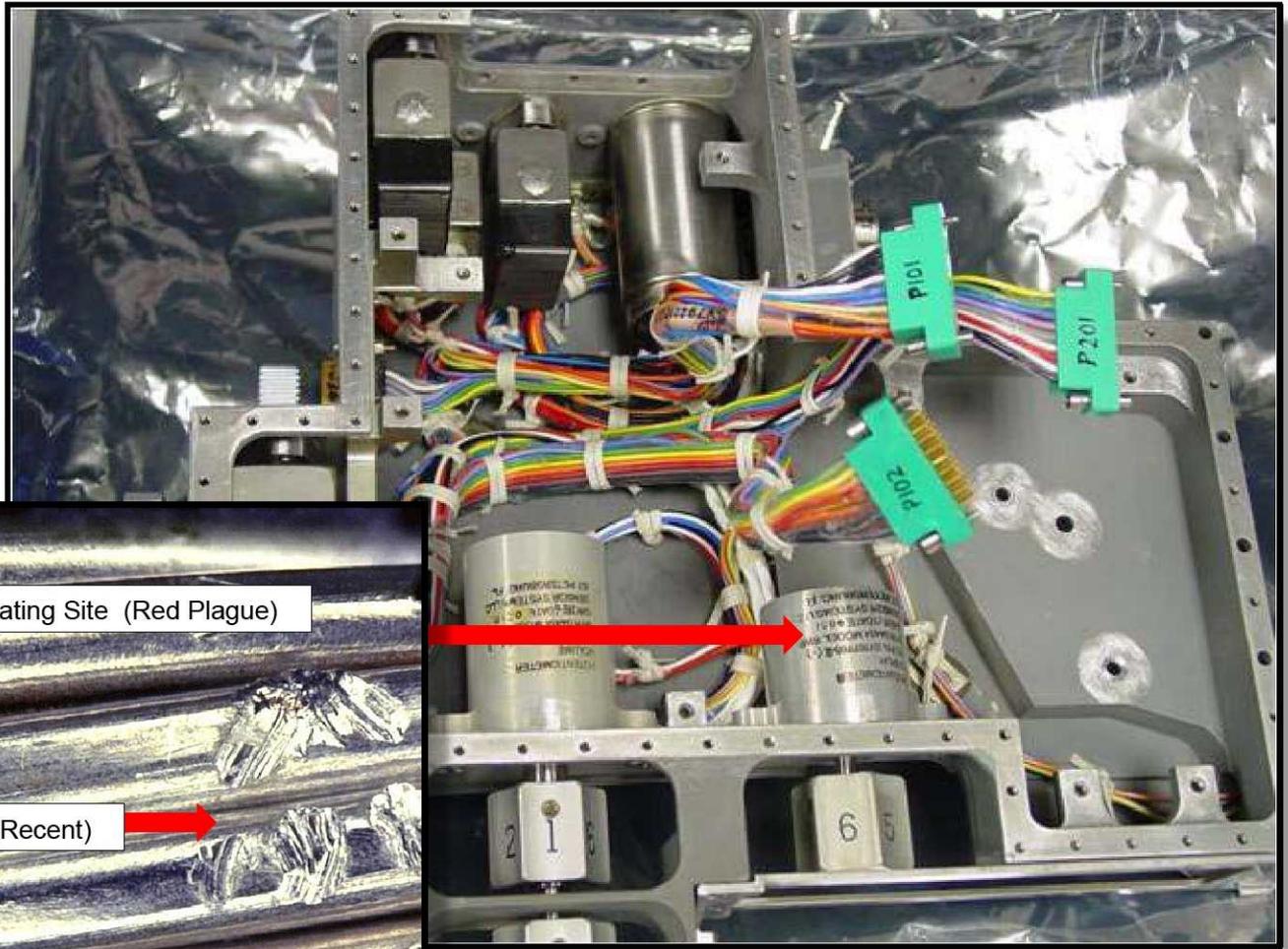
- **CONTRACT CHANGE RESULTED IN A JSC WAREHOUSE FULL OF WIRE**

- Some wire believed to be more than 15 years old – no QA paperwork
- Wire reportedly all Flight (Class A), but not identified as such – no QA paperwork
- Retesting / recertifying all of the wire through JSC RITF would have swamped the lab

- **NOT ON CONTRACT**

**\$\$\$ Schedule impact if implemented / \$\$\$ Cost savings if not implemented**

# BUT --- RED PLAGUE CONFIRMED IN FLIGHT HARDWARE (JANUARY 2010)



# **JSC 64647 – RED PLAGUE CONTROL PLAN (RPCP)**

## **THE CONTROL OF CUPROUS / CUPRIC OXIDE CORROSION (RED PLAGUE) IN SILVER-COATED COPPER WIRE, CABLE, AND HARNESS ASSEMBLIES**

- **SCOPE**

- Prescribes the minimum requirements for the control of cuprous / cupric oxide corrosion (a.k.a. Red Plague) of silver-coated copper wire, cable, and harness assemblies.

- **PURPOSE**

- Targeted for applications where exposure to assembly processes, environmental conditions, and contamination may promote the development of cuprous / cupric oxide corrosion (a.k.a. Red Plague) in silver-coated copper wire, cable, and harness assemblies.
- Does not exclude any alternate or contractor-proprietary documents or processes that meet or exceed the baseline of requirements established by this document. Use of alternate or contractor-proprietary documents or processes shall require review and prior approval of the procuring NASA activity.

- **APPLICABILITY**

- All JSC projects and programs involved in the design, manufacture and inspection of electronic, electrical and electro-mechanical hardware, and printed wiring assemblies (PWA) for Aerospace And High Performance (AHP), spaceflight and mission essential support equipment applications.

# JSC 64647 – RED PLAGUE CONTROL PLAN (RPCP)

- **CONDUCTOR STRAND MATERIAL AND COATING**

- All strands shall conform to the applicable ASTM or ANSI standards for the proper material listed in Table 1.
- After stranding, strands shall be free from lumps, kinks, splits, scraped or corroded surfaces, and skin impurities.

TABLE 1	CONDUCTOR STRAND MATERIAL AND COATING		
Designator	Strand material	Thickness	Application ASTM or ANSI standard
SCC	Annealed copper	1 MICRON (~40 MICRO-INCH)	ASTM-B298
SCC1	Annealed copper	2 MICRON (~80 MICRO-INCH)	ASTM-B298 ASTM-B961
SCA	High strength copper alloy	1 MICRON (~40 MICRO-INCH)	ASTM B298 ASTM-B624
SCA1	High strength copper alloy	2 MICRON (~80 MICRO-INCH)	ASTM B298 ASTM-B624 ASTM-B961
SCU	Ultra-high strength copper alloy	1 MICRON (~40 MICRO-INCH)	None

# JSC 64647 – RED PLAGUE CONTROL PLAN (RPCP)

- **SILVER COATING REQUIREMENTS**

- 1 MICRON (~40 MICRO-INCHES)

Primary and shield conductors: Not less than 1 micron (~40 micro-inches) average, when measured in accordance with ASTM B 298-07.

- 2 MICRON (~80 MICRO-INCHES)

Primary and shield conductors: Not less than 2 micron (~80 micro-inches) average, when measured in accordance with ASTM B 298-07. After stranding, the coating thickness on each of the individual conductor strands shall not be less than 1 micron (~40 micro-inches) when inspected using micro-section analysis in accordance with ASTM B 961-08.

- SODIUM POLYSULFIDE TEST

The continuity (non-porosity) of the coating shall be determined on representative samples by the sodium polysulfide test, in accordance with ASTM B 298–07.

- RED PLAGUE CORROSION TEST

Representative samples shall conform to codes 0 – 3 of the accelerated corrosion test for un-insulated silver-plated conductors as outlined in ASTM B 961-08 [9.2].

- MICRO-SECTION ANALYSIS

Micro-section inspections shall be in accordance with ASTM B 961-08 except that the coating thicknesses specified herein shall be in effect.

# JSC 64647 – RED PLAGUE CONTROL PLAN (RPCP)

- **PROCUREMENT REQUIREMENTS**

- **QUALIFIED / APPROVED SUPPLIERS**

- Procured in accordance with the wire procurement specification, from suppliers listed on the Qualified Manufacturers List (QML) or suppliers approved by the procuring NASA activity.

- **LOT TRACEABILITY AND CERTIFIED TEST REPORTS**

- Full lot traceability and certified test reports.

- Test reports, and all tested and untested micro-section analysis coupons, shall be preserved and available for review by the procuring NASA activity on request.

- **LIMITED LIFE ARTICLE**

- Stock wire and cable with a shelf life exceeding 10 years from manufacturing date shall be segregated and shall not be used on in harness assemblies and hardware.

- Completed cable, harness assemblies, and hardware incorporating silver-coated copper wire and cable, with a combined storage and use life exceeding 10 years from date of assembly **shall** be identified, periodically inspected and tested, and tracked as a “Limited-Life Article”.

# JSC 64647 – RED PLAGUE CONTROL PLAN (RPCP)

- ENVIRONMENTAL REQUIREMENTS

- Silver-coated copper wire and cable shall be protected to reduce and control exposure to environmental conditions and contamination that promote the development of cuprous / cupric oxide corrosion (Red Plague).

- SHIPPING AND STORAGE

Shipped and stored in sealed water-vapor-proof packaging (i.e.: Moisture Barrier Bag, dry pack, etc.), with capped ends, activated desiccant, and an irreversible humidity indicator card (i-HIC). Wire and cable **shall not** be stored in paper wrapping materials or cardboard boxes.

Packaging. MIL-STD-2073-1E Method 51. Moisture Barrier Bags (MBB) shall meet MIL-PRF-81705, TYPE 1.

Capping. Wire and cable ends shall be capped with heat shrinkable end-caps conforming to SAE-AMS-DTL-23053/4, or dipped in insulating electrical varnish for a length of approximately 2.5 cm (1 in).

Desiccant (Activated). MIL-D-3464 Type 2. The minimum quantity of desiccant to be based on the protective package's interior exposed surface area, in accordance with MIL-STD-2073-1E, Method 50, Formula 1.

Irreversible Humidity Indicator Card (i-HIC). Irreversible Indication (50-60-70-80-90% RH), or a combination Irreversible / Reversible Humidity Indicator (50-60-70-80-90% RH) conforming to MIL-I-8835.

# JSC 64647 – RED PLAGUE CONTROL PLAN (RPCP)

- ENVIRONMENTAL REQUIREMENTS (cont.)

- ASSEMBLY

All assembly processes, including Receiving Inspection and Kitting, **shall** be conducted in an environmentally-controlled and monitored area where dew point is not attained and the relative humidity is less than 70%RH.

Wire and cable **shall not** be removed from its protective packaging until it has reached thermal equilibrium with the assembly environment to reduce the risk of condensation formation.

#### Unused Wire

Prior to returning wire back to storage, wire ends **shall** be capped and stored in water-vapor-proof packaging **OR** an environmentally-controlled and monitored area where dew point is not attained and the relative humidity is less than 70%RH.

#### Work In Progress

Stored in water-vapor-proof packaging **OR** an environmentally-controlled and monitored area where dew point is not attained and the relative humidity is less than 70%RH.

#### Completed Hardware

Stored in water-vapor-proof packaging **OR** in an environmentally-controlled and monitored area where dew point is not attained and the relative humidity is less than 70%RH.

#### Cleaning

Aqueous solvents and cleaning systems **shall not** be used.

